CHAPTER 11. LOW/MEDIUM FREQUENCY (L/MF) GROUND NAVIGATIONAL AIDS

1100. PURPOSE. The purpose of this chapter is to describe the necessary techniques and actions required to provide a frequency for a low/medium frequency (L/MF) NAVAID. L/MF includes Compass Locator (COMLO) and Nondirectional Beacon (NDB), also known as "Homer."

a. The COMLO is an NDB, usually of low power, strategically located on an ILS approach path to provide L/MF azimuth guidance to an airport, in addition to the more precise guidance of the ILS LOC. COMLO's are normally collocated with ILS Outer Markers (OM) and Middle Markers (MM), and referred to as "LOM" and "LMM," respectively. The LOM transmits, in Morse code, the first two letters of the associated ILS identifier. The LMM transmits the last two letters of the associated ILS identifier. For example, COMLO's installed with the Los Angeles, CA (LAX) ILS would be "LA" for the LOM and "AX" for the LMM. To the extent possible, the frequencies of the LOM and LMM shall not be separated less than 15 kHz nor more than 25 kHz.

b. The NDB is a free-standing nondirectional radio beacon designed to provide navigational service over a specified radial distance from the facility. It can have power from 10 W to 1000 W, typically 25 W, depending on the need. It should be noted that due to very heavy congestion in this band, the FMO shall do everything possible, by coordinating with AT and FS, to engineer the lowest possible emitted power to cover the requirement. The National flight Data Center (NFDC) is responsible for the coordination of requests for three-letter location identifiers. Coordination with NFDC is accomplished by each region through the AT Operations Branch.

1101. GENERAL CONSIDERATIONS.

a. NDB and COMLO are treated the same for frequency assignment purposes. For simplicity, only the term NDB will be used hereafter when it is intended to refer to both.

b. An NDB frequency selection model is available on the AFM for engineering NDB requirements.

c. A required signal level of 70 microvolts per meter (µv/m), which is also 37 dB above one microvolt per meter (dBµv/m), is the standard set for the signal required at all points on the outer limits of the NDB FPSV. If the NDB transmitter power decreases by 3 dB, the resultant signal would be equivalent to 50 µv/m at all points on the outer limits of the NDB FPSV. At this point, the remote NDB alarm is triggered.

d. The D/U signal level standard for NDB's is 15 dB. This provides an assured 12 dB protection of the FPSV when the desired signal decreases 3 dB from the normal operating power. At this point, the system should alarm.

e. Channelization of the band is 1 kHz. First adjacent channel is 1 kHz removed, second adjacent is 2 kHz removed, etc.

f. The mode of radiation is considered to be groundwave, while acknowledging that, particularly at night, skywave does enter into propagation mode.

g. The FPSV is considered to be a cylindrical volume of airspace, centered on the NDB, with no upper altitude limit. Since the groundwave is the principal radiation factor, the signal level in any given direction is a function of the antenna efficiency, the ground system associated with the antenna and the ground conductivity medium through which the signal passes to get to the point under consideration.

h. NDB FPSV's are classified as follows:

(1) LOM/LMM	15 nmi radius
(2) MH (less than 50 W)	25 nmi radius
(3) H (50 w or more, but less than 2,000 W)	50 nmi radius
(4) HH (2,000 W or more)	75 nmi radius

i. An NDB's primary function is as a NAVAID, However, voice modulation is permitted in addition to the required Morse code identifier only on a secondary basis, and then only when it causes no interference to any other facility as a result of the additional voice modulation.

j. An NDB for non-Federal use, which requires a frequency request through FCC, has the same priority as an FAA or other Federal agency facility, provided that the proposed NDB has an FAA approved procedure on it. Any other non-Federal use is on a secondary basis, assignable only if:

(1) The facility could be accommodated without moving or otherwise affecting FAA facilities in any way.

(2) FAA concurrence with use of the frequency is contingent upon the frequency being withdrawn upon notice by FAA in writing at any time it is needed for a facility which has a procedure and is in the NAS.

k. Permissible power is that normal power level which just meets the level required to assure 70 µv/m at the circumference of the FPSV. In some unique instances, due principally to poor ground conductivity, it may be impossible to meet the signal level requirement at some azimuths. In this case, an option, if FS and AT concur, could be to commission with restrictions.

l. There is little difference in the signal level between ground and any altitude normally flown by aircraft within the FPSV specified. As a general rule, the signal level measured at any altitude is considered to be the same as found at ground level and all other altitudes at that azimuth.

m. A dual carrier NDB has an upper sideband (only) with full carrier. It radiates a Continuous Wave (CW) carrier on the assigned frequency. The identification signal is provided by an on/off keying of a second carrier, transmitted at a frequency equal to the first carrier frequency plus the frequency of the modulation tone. For example, at a carrier frequency of 200 kHz, the second carrier would be at 200.4 kHz (for a 400 Hz identifier) and at 201.02 kHz (for a 1020 Hz identifier). For purposes of registering in the GMF, the emission designator would be 500HXXA and the center frequency would be 200.2 kHz (for a 400 Hz identifier) and 1.112XXA emission designator and 200.51 kHz center frequency (for a 1020 Hz identifier).

1102. FREQUENCY ALLOCATION FOR L/MF FACILITIES. The frequencies allocated for L/MF use are shown in figure 11-1.

FIGURE 11-1. L/MF NAVAID FREQUENCY ALLOCATIONS

Frequency (kHz)	Limitations & Comments
190 - 200	AR Primary
200 - 275	AR Primary; AM Secondary
275 - 285	AR Primary; AM Secondary; MR Secondary
285 - 325	MR Primary; AR Secondary
325 - 335	AR Primary; AM Secondary; MR Secondary
335 - 405	AR Primary; AM Secondary
405 - 415	R Primary; AM Secondary
415 - 435	MM Primary; AR Primary
510 - 525	AR Primary; MM Primary
525 - 535	AR Primary; M Primary

KEY

AR - Aeronautical Radionavigation (FAA & Non-Fed. NDB's)
AM - Aeronautical Mobile
MR - Maritime Radionavigation
R - Radionavigation
MM - Maritime Mobile
M - Mobile

(For detailed definitions, see NTIA Manual, Chapter 6.)

a. NDB voice is not permitted in the bands 190-199.9, 285-324.9, and 415-535 kHz.

b. The band 525-535 kHz use by Mobile Service is limited to the Travelers' Information Service (TIS), operating on 530 kHz. Voice modulation of NDB's is not permitted in this band. AR stations are authorized for off-shore use only, on a non-interference basis to TIS.

c. Maritime radiobeacons in the 285-325 kHz band segment will not be used for aeronautical operations. In addition, FMO's will avoid use of the 285-325 kHz band segment for aeronautical radiobeacons because of the incompatibility between aeronautical NDB receivers and the maritime NDB's which transmit DGPS signals for use by maritime users.

1103. ENGINEERING CONSIDERATIONS FOR L/MF FREQUENCY SELECTION. It is unfortunate, but frequency engineering for L/MF facilities is not a straight-forward technical operation. There are several reasons for this.

a. L/MF propagation is not an omnidirectional straight line decay of signal situation. Since groundwave is involved to a considerable degree with the conductivity of the ground in each azimuth direction, there can be wide variations of signal strength in different directions from a single antenna.

(1) An antenna near a body of water, particularly ocean water, will have greatly increased radiation in the azimuths covered by the ocean, while inland azimuths will retard radiation due to signal losses caused by poorer conducting earth. As an example, an NDB on the northern Florida east coast will have very efficient radiation into the Atlantic Ocean. But because the ground conductivity is very poor there, signals radiated to the west would be much reduced.

(2) A specific example would be that at 50 nmi to the west, a signal of 20 µv/m would be measured from a 25 W NDB. The same signal measured eastward to sea (assuming the NDB to be on or very close to the beach) would produce 70 µv/m, or an approximately 11 dB stronger signal.

(3) Night-effect can occur because an NDB radiates both a groundwave and a skywave. The groundwave is usable for navigation within the operational service volume. The skywave is radiated up into space and reflected back to earth by the ionosphere. This reflection results in the presence of an attenuated skywave at varying distances from the NDB ground station. The distance and the amount of attenuation are determined by the height and density of the ionosphere and the angles at which the radiated skywave strikes the ionosphere. Skywave field strength is subject to changes in the ionosphere. This is similar to the conditions for HF described in chapter 7. These changes occur as a function of the time of day, time of year and phase of the solar cycle. At night, the reflective property of the ionosphere increases for L/MF and the lower HF bands resulting in a skywave field strength that can be substantially larger than during the day.

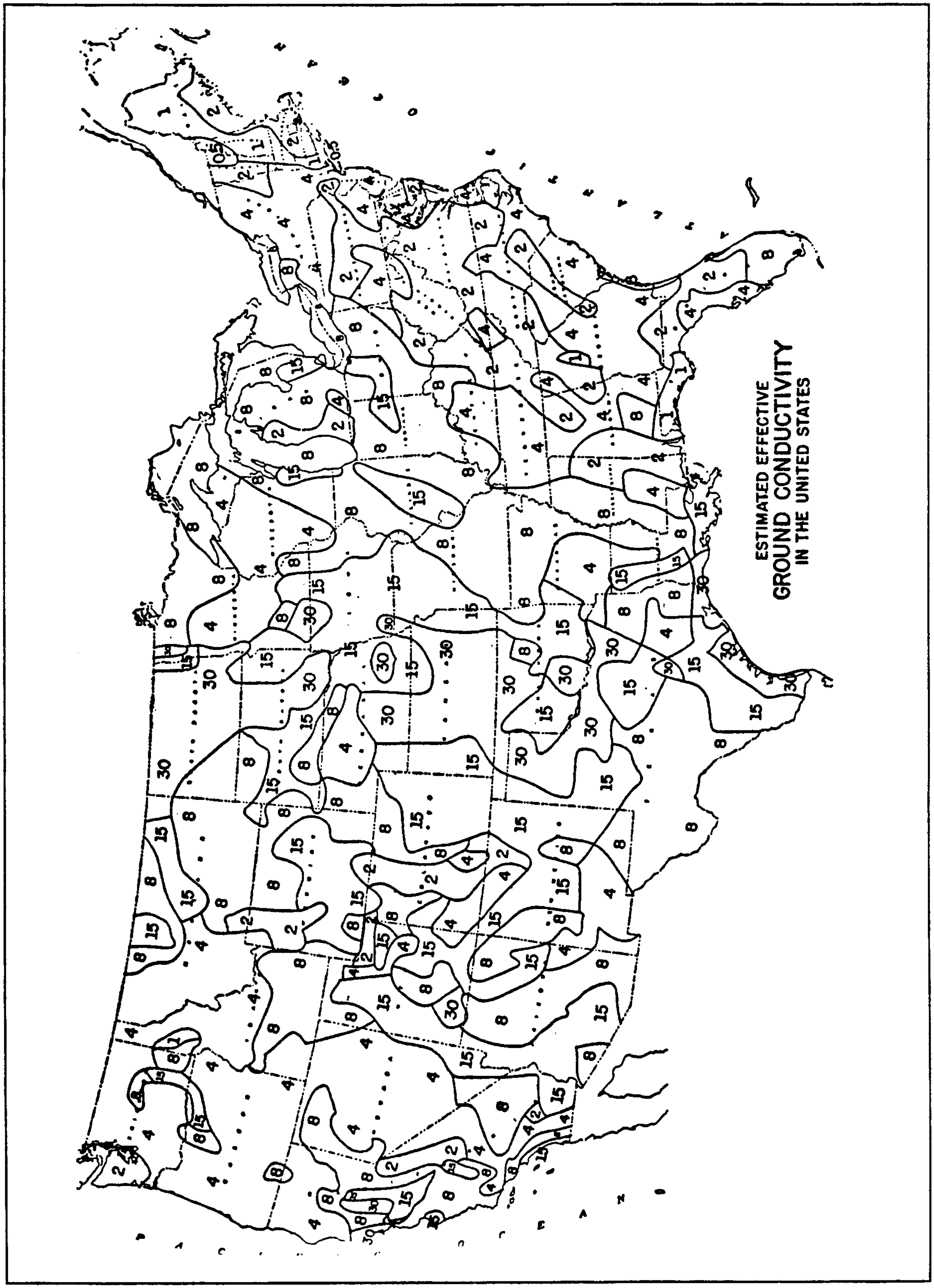
b. A ground system consisting of four copper wires, equally spaced radially about the base of the antenna, would give a smaller signal at any given point as compared to the same antenna with 30 equally-spaced copper radials.

c. There are no "standard" antennas, so whatever antenna is installed will affect the radiation efficiency. The most common antennas used are the symmetrical "T" and the top loaded vertical or "Top Hat."

d. Ground conductivity charts are only approximate, and the various curves used are an average of empirical data.

e. With all those limitations, it can be seen that the process which will be described is only an estimate of the level of signal to be expected at the periphery of the FPSV.

FIGURE 11-2. ESTIMATED GROUND CONDUCTIVITY IN THE UNITED STATES



1104. BASIC TOOLS. The basic tools used in engineering frequencies for L/MF are the ground conductivity map and the prediction curves.

a. The Ground Conductivity Map. Refer to figure 11-2. The conterminous U.S. (CONUS) is divided up into small "jig-saw" segments with numbers in each piece. Those numbers are the numerical value of "millimho/m" (mm/m) and represent units of reluctance, the unit used to represent average electrical conductive quality of the ground in the area. A value of 1 to 4 is poor; 8 is good; 15 and 30 are so good that they are practically indistinguishable from sea water. Sea water, the reference at 4,000, is the ideal. These values will be more meaningful when they are compared with the other tool, the coverage and interference prediction curves.

b. Prediction Curves. Refer to figure 11-3. These curves are designed to give the user a predicted level of signal at a given distance from the transmitter. The three shaded curves are for "poor" ground at 1 to 4 mm/m, "good" ground at 8 mm/m and sea water at 4000 mm/m. Conductivity values between 1 and 4000 must be interpolated.

(1) There is a frequency factor in the curves. The frequency range covered is over 2:1. Conductivity varies with frequency so that the left side of each curve is 400 kHz and the right side is 200 kHz. Frequencies in between must be interpolated.

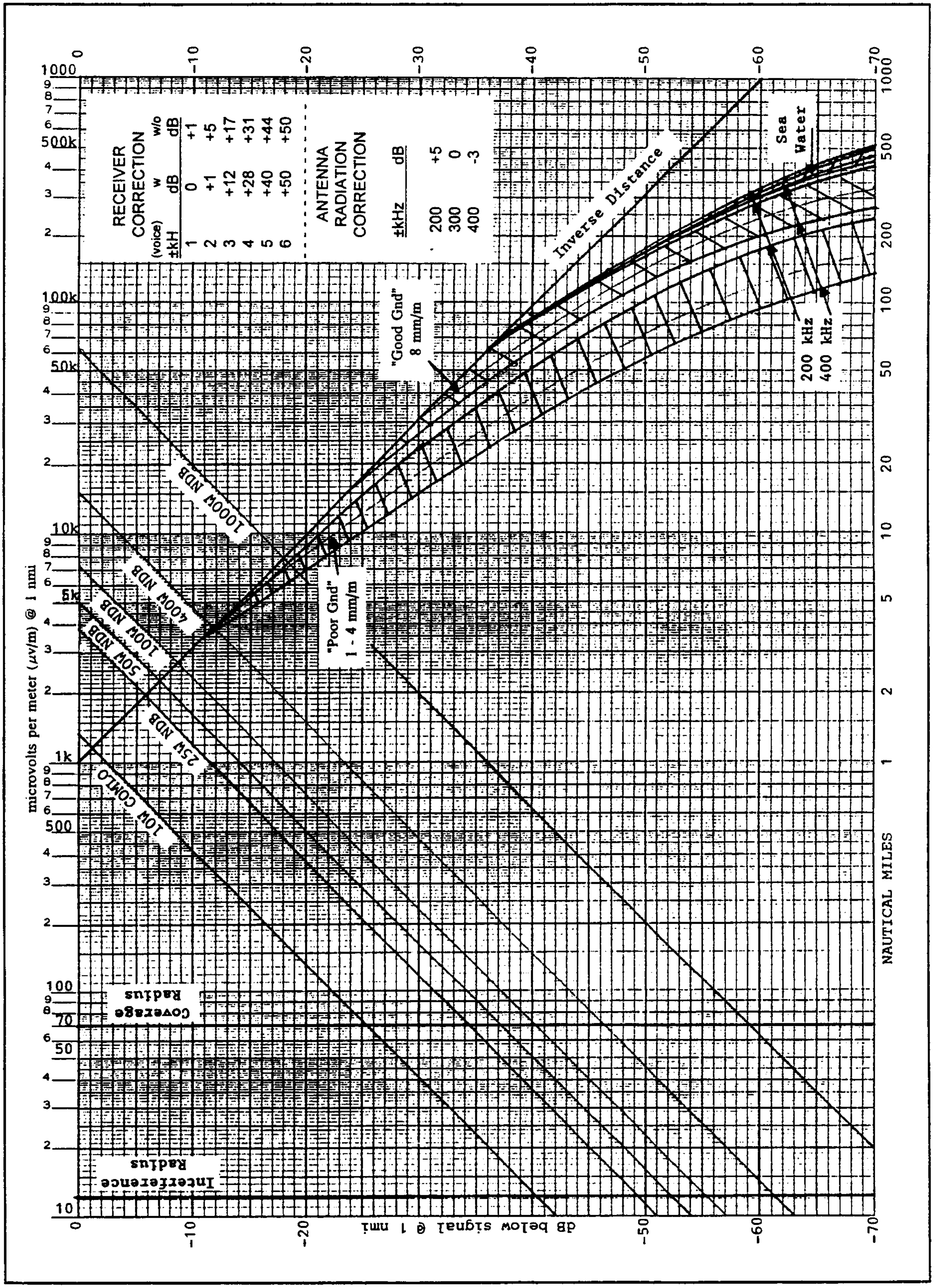
(2) The curves are normalized to 300 kHz and so have an antenna efficiency factor which is shown between 200 kHz and 400 kHz. The antenna radiation correction factor for frequencies in between must be interpolated.

(3) There are corrections for receiver intermediate frequency (IF) selectivity. While newer receivers will have quite sharp IF selectivity, until such time as the large majority of airborne receivers are of that group, the receiver correction values shown on the chart shall be used.

(4) Typical facility types, as related to average radiation level from usual antennas, are shown as a series of parallel straight lines. Where the line intersects the 0 dB abscissa, the indicated µv/m value (good only on the "0 dB" line) is that predicted at 1 nmi.

(5) The vertical scale for the abscissas is the dB value below signal voltage level at 1 nmi. For instance, the 25 W NDB line shows an expected level of 3700 µv/m at 1 nmi. Its intersection with the 70 µv/m service radius at the -34.5 dB abscissa, when followed to the inverse distance line, indicates that a level of 70 µv/m would occur over perfectly-conducting ground at 50 nmi. In propagation, field voltage decays inversely as the distance. Power varies inversely as the square of the distance. A signal voltage at 2 nmi is 6 dB less than that signal level at 1 nmi. The "inverse distance" line runs from 1 mv/m to 1000 mv/m. The distance and voltage are inversely proportional and their ratio is 1000:1. It can be seen that dB = 20 log (E1/E2) = 20 log 1000 = 20 X 3 = 60 dB. The inverse distance line is from 0 to -60 dB.

FIGURE 11-3. COVERAGE AND INTERFERENCE PREDICTION CURVES



1105. ENGINEERING PROCEDURES.

a. Conductivity. Required facility geographical separation (S) is calculated by using figures 11-2 and 11-3. Figure 11-2 shows the ground conductivity in mm/m which determines which curves to use in figure 11-3.

b. Separation Distance (S). (S) is the minimum distance required between facilities to prevent interference and is defined as:

$$\boxed{(S) \geq d_D + d_U}$$

where d_D = distance from the desired facility to the edge of its service volume

d_U = distance from the undesired facility to the edge of the desired service volume

c. Calculation of Required Separation Distance.

(1) Find the facility service volume d_D in nmi on the bottom of figure 11-3. Move up to intersect the appropriate ground conductivity curve from figure 11-2, interpolating for frequency. Note the attenuation value in dB at the left of figure 11-3.

(2) Add the antenna radiation correction factor shown in figure 11-3 to the dB value in subparagraph 1.

(3) Algebraically add the correction factor to subparagraph 2 for difference in facility power. For example, if the undesired facility is 50 W and the desired facility is 25 W, add -3 dB.

(4) Add the receiver correction value to subparagraph 3 when the undesired station is within ±6 kHz of the desired station. The "Undesired receiver correction with voice" shall be used first. If a frequency cannot be engineered using that value, the "Undesired receiver correction without voice" may be used only if the desired station does not have transmit voice.

(5) Algebraically add -15 dB to the value obtained in subpara. 4; this gives the D/U ratio of 15 dB required.

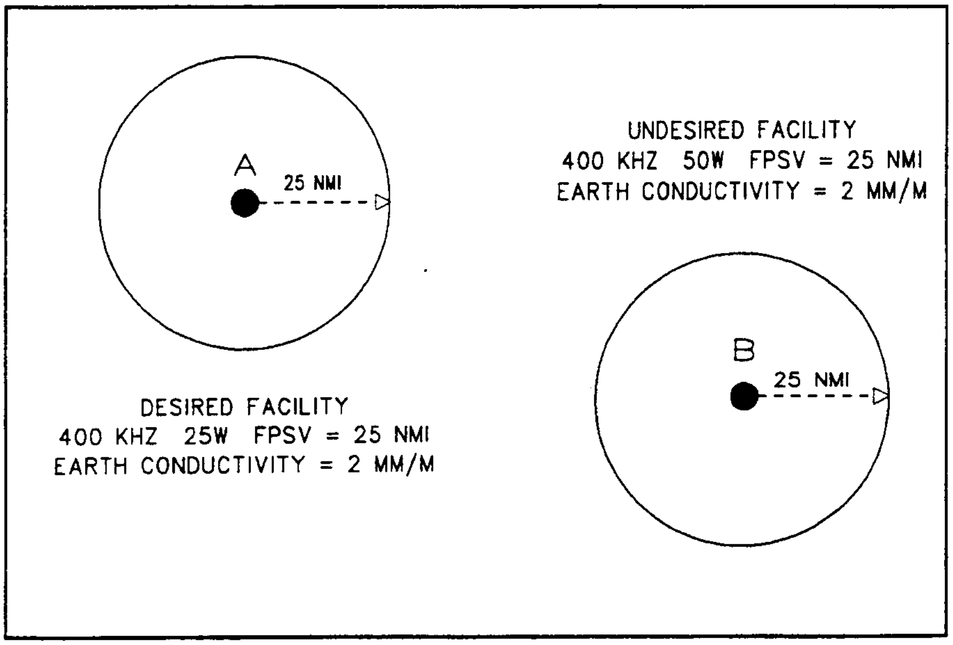
(6) Use the dB attenuation value obtained in subparagraph 5 and find this level at the left of figure 11-3. Move across to intersect the appropriate conductivity curves. This intersection determines d_U in nmi from the bottom scale.

(7) Add d_D and d_U to obtain the required separation (S) distance necessary for the desired facility to have a minimum of 15 D/U.

(8) Determine the required (S) for the undesired facility in the same manner (now the undesired is the desired and vice versa).

1106. PRACTICAL EXAMPLE. See figure 11-4.

FIGURE 11-4. GEOGRAPHIC SEPARATION EXAMPLE



a. Station A, the desired station, is on 400 kHz, power 25 W, FPSV 25 nmi, with conductivity of 2 mm/m.

b. Station B, the undesired station, is on 400 kHz, power 50 W, FPSV 25 nmi, also 2 mm/m.

c. Calculating Station A Distances.

(1) Find the facility d_D of 25 nmi FPSV at the bottom of figure 11-3. Move up and intersect the 400 kHz 2 mm/m curve. Note the attenuation value of -37.5 dB at the side of the graph.

(2) Algebraically add -3 dB radiation correction factor to the value of subparagraph 1: -37.5 + (- 3)2= -40.5 dB.

(3) Determine the dB power difference: P_D/P_U = 25/50. 10 log ½ = -3 dB. Add that value to the value of subparagraph 2: -40.5 - 3 = -43.5 dB.

(4) Determine the receiver correction value. In this example, the stations are on the same frequency, receiver correction is 0 dB, so the value remains -43.5 dB.

(5) Algebraically add -15 dB to the value obtained in subparagraph 4: -43.5 dB + (- 15) = -58.5 dB.

(6) Find the value -58.5 dB at the left of figure 11-3 and move across to intersect the 400 kHz curve for 2 mm/m. From the scale at the bottom of the graph, note the value is 90 nmi.

(7) Add d_D + d_U = 25 + 90 = 115 nmi, the required separation for (S).

d. Calculating Station B Distances.

(1) Find the facility FPSV d_D of 25 NM at the bottom of figure 11-3. Move up and intersect the 400 kHz 2mm/m curve. Note the attenuation value of -37.5 dB. See subparagraph c(1).

(2) Algebraically add -3 dB antenna radiation correction factor to value of subparagraph 1: -37.5 + (- 3) = -40.5 dB.

(3) Determine the dB power difference: P_D/P_U = 50/25. 10 log 2 = +3 dB. Add that +3 db to the value of subpara. 2: -40.5 dB + 3 = -37.5 dB.

(4) Determine the receiver correction factor to be 0 dB, so the value remains at -37.5 dB.

(5) Algebraically add -15 dB to the value in subparagraph 4: -37.5 + (-15 dB) = -52.5 dB.

(6) Find the value -52.5 dB on the side of figure 11-3 and move across to intersect the 400 kHz 2 mm/m curve. Note the value is 65 nmi.

(7) Add d_D + d_U = 25 + 65 = 90 nmi, the required (S).

(8) Compare the required separations for each calculation. Note that the larger requirement is 115 nmi, and the larger is always used.

1107. AIRBORNE MEASUREMENTS.

a. The same kind of measurements (for the proposed facility) could be made from a flight inspection aircraft. The problem is in the receiving antenna in the aircraft. A calibrated loop remains as a calibrated entity only as long as its surroundings are nominal, or at least not changing. With a loop on an aircraft, any change of aircraft position with respect to the plane of the loop which has to be maximized with respect to the signal source will nullify its calibration. The cost of using a flight inspection aircraft is prohibitive to be used as a "study" vehicle.

b. A FAA Study covering a comparison of airborne and ground measurement was completed in 1980. A thorough report of that study is available for FMO consideration in Report No. FAA-R-6050.2, Low Frequency Beacon Signal Strength Determination, dated January 1980.

1108.-1199. RESERVED.